

CCSDS Link Budget Weather Related Losses

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1. Abstract

The following paper describes the method used in computation of weather losses, namely the atmospheric attenuation and the system noise temperature increase due to weather. The method uses the model developed for NASA/JPL/DSSN tracking stations and is suggested as the first order approximation value to be entered into the Consultative Committee on Space Data Systems (CCSDS) link budget program to get a preliminary understanding of the link

2.1. Introduction

The CCSDS is currently in the process of producing a CCSDS link budget program for use by the member agencies who are engaged in joint missions with cross support to provide the link parameter values, either common or assumed, to all the involved agencies. This CCSDS link budget is an executable tool to compute link performance efficiently with minimum user effort in gathering necessary parameter values. However, to compute the output value link related needs are pertinent input values. Most input values pertain to satellite receive/transmit system or the ground transmit/receive system and the design of the satellite has reached a certain stage, these values are known a reasonable degree of confidence and can be used on the link budget. The same input parameters that do not fall under the categories of the transmit/receive or ground segments of the link, these belong to the weather and related parameters category. CCSDS calls these as the "Space Path Parameters" and "Space-to-Earth Path Parameters" of the link. These parameter values are

readily available and are dependent upon the weather, elevation angles of the antennas, frequency used, etc., and may even be affected by the diurnal changes

This paper gives some already-existing models that can be used to obtain the values of these weather-related losses to be entered into the CCSDS link budget program so that the link performance can be computed. It should be noted that the loss values predicted by the models given below may not be quite applicable to the user's particular situation, but they are intended to help the user to provide reasonable estimates of the losses in the link budget. It allows the presentation is done in terms of the CCSDS link budget, however, the parameter values generated by using the models can be used in any other link budgets.

3.4 Theory

The CCSDS link budget has eight pages. The first page is file-keeping information. The second, third and fourth pages are the input pages for the Earth-to-Space link and Space-to-Earth link. The fifth and sixth pages are the uplink and downlink performance parameters, respectively, and pages seven and eight are the notes about the link. The user is supposed to supply the values of parameters contained in the first four pages and the results are computed and shown in the fifth and sixth pages. This paper discusses the atmospheric losses and the weather-related temperature-increase.

4.0 Atmospheric Losses and Weather-Related System Noise Temperature Increase

The total noise density associated with the ground receiving station is a function of the weather around the ground station antenna along with the other usual sources of the noise temperature. The weather around the receiving station, basically, the physical temperature of the weather, adds a temperature increase to the temperature of the receiver. To estimate this temperature increase, the weather statistics have to be compiled at the specific receiving station and documented. From this statistical data, one can obtain a cumulative weather distribution (CDF) at the station on the antenna site. As an example, CDF = 0.9 implies that 90% of the time the temperature increase is less than a given value. The temperature increase is a function of the physical temperature at the antenna site, the atmospheric

attenuation to the propagating wave, and the antenna elevation angle should be noted that all these parameters are station location dependent making the resulting empirical model station location dependent.

As an example, the empirical model developed for the NASA/JPL/DSSN stations will be explained (reference 1) here. The physical temperature, T_p is related to the CTD by the following empirical equation:

$$T_p = 265 + 15(CT) \quad (\text{Kelvins}) \quad (1)$$

where $CT = T_p - T_0 \approx T_p - 280$ (K). A database exists for providing the attenuation at zenith at S-band, X-band, and Ka-band frequencies. Using this information at zenith, say z_1 dB (it should be remembered that according to the CCSDS recommendations, the losses should be in negative dB) the attenuation at an antenna elevation angle of α , denoted by $z_{1\alpha}$ is calculated by

$$z_{1\alpha} = z_1 \sin(\alpha) \quad (2)$$

The system noise temperature increase is then computed using the physical temperature around the antenna site and the attenuation computed at the elevation angle α using the following formula:

$$\text{System Noise Temp Increase} = T_1 \left[10^{\left(\frac{z_{1\alpha}}{10} \right)} \right] \quad (\text{K}) \quad (3)$$

As an example of the empirical model, the temperature increase for $CT \approx 0.998$ and $\alpha = 20$ degrees, from the database, $z_{10} = 0.0355$ dB and the quantity $z_{1\alpha}$ is computed to be 0.14 dB and T_p is computed to be 280 (K) and finally the system noise temperature increase is calculated to be 6.6 (K). It should be noted that the system noise temperature calculated using the above formula is the increase over the system noise temperature at zenith and should be added to the zenith system noise temperature.

can be seen that as C/D becomes closer to 1, i.e., the closer it is to be operative regardless of the weather, the degradation to be considered on the link is large. The value of C/D = 0.95, or 95%, seems to be sufficient on the link.

It should be clear that the model described above is valid only for the NASA/JPL/DSSN stations around the world. The zenith attenuation is a function of the latitude and longitude of the station. As an example, the zenith attenuation of the NASA/JPL/DSSN Goldstone stations is different from NASA/JPL/DSSN Madrid or Canberra. This is so because the weather statistics at each of these stations is different. This in turn makes the system noise temperature increase different for the different stations. The ground station the user is associated with, will have its own zenith attenuation and physical temperature calculation empirical formulas and may be significantly different than described above and hence the user should use considerable caution in using the model described above. In any case, the model is given to provide an estimate of the atmospheric attenuation and the system noise temperature increase.

The following figures plot the above equations. As the figures are plotted on the JPL/DSSN tracking stations a Goldstone, California. Figure 1 shows the zenith attenuation of as a function of the cumulative weather distribution. The cumulative weather distribution is varied from 80% to 99.8% and the graphs are plotted for the S-band, X-band and K-band frequencies shown on the plot. The values of the zenith attenuation are measured and are not generated using a theoretical model. Alternately, the zenith attenuation may be obtained by using the already existing CCIR models and the weather regions map. Once the zenith attenuation is obtained, the atmospheric attenuation and the system noise temperature increase is obtained using the above models. Figure 2 shows a plot of the variation of the atmospheric attenuation as a function of the receiving antenna elevation angle. The atmospheric attenuation is described by equation (2). Figure 3 plots the system noise temperature increase as a function of the antenna elevation angle. Again, it should be remembered that these values and plots are only for the JPL/DSSN tracking station at Goldstone, California and similar procedures have to be followed to obtain the atmospheric attenuation and the system noise temperature increase for different tracking stations around the world. The actual value of attenuation and the system noise temperature increase depends upon the frequency used and the moisture content of the atmosphere on the region.

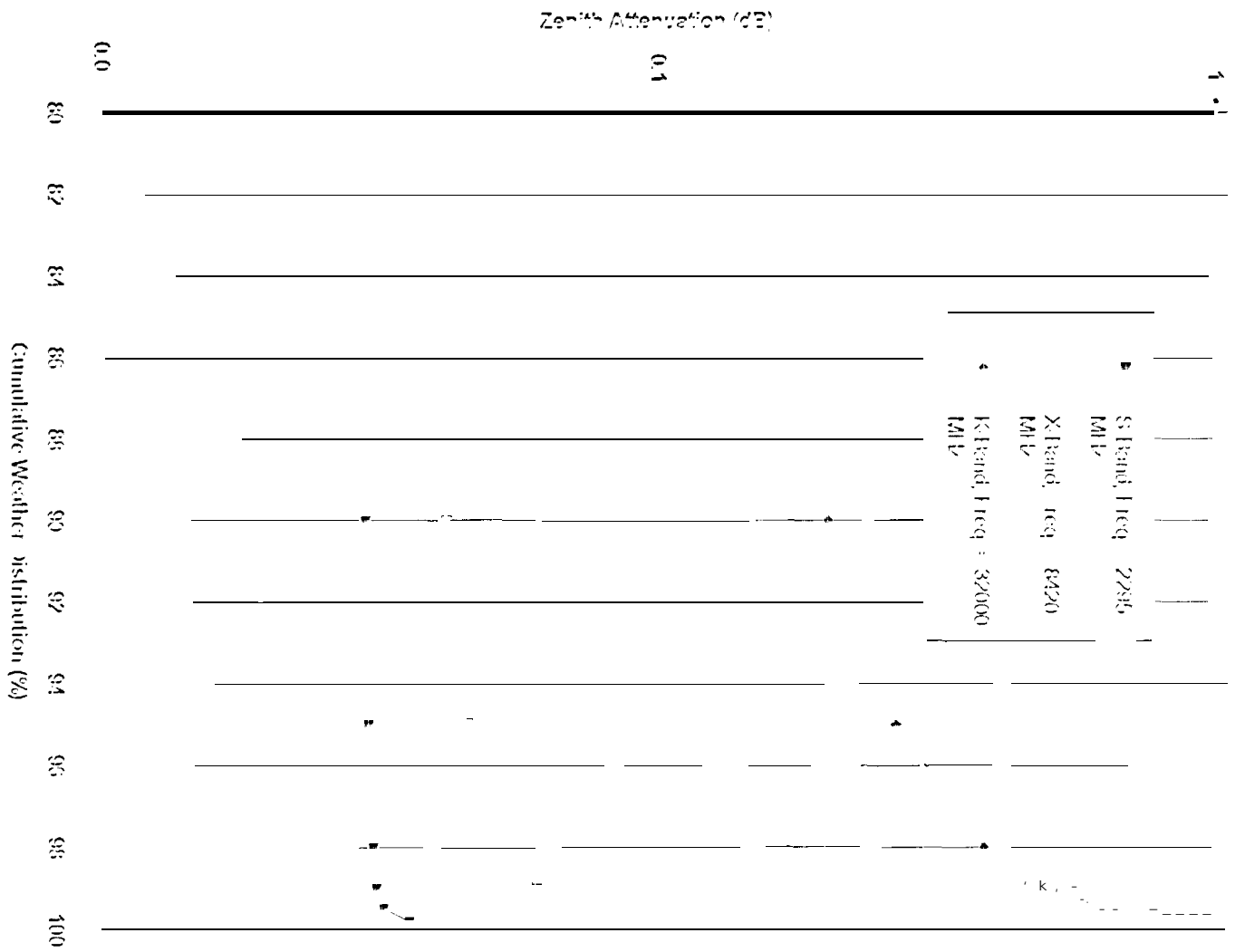


Figure 1. Zenith Attenuation as a Function of Cumulative Weather Distribution

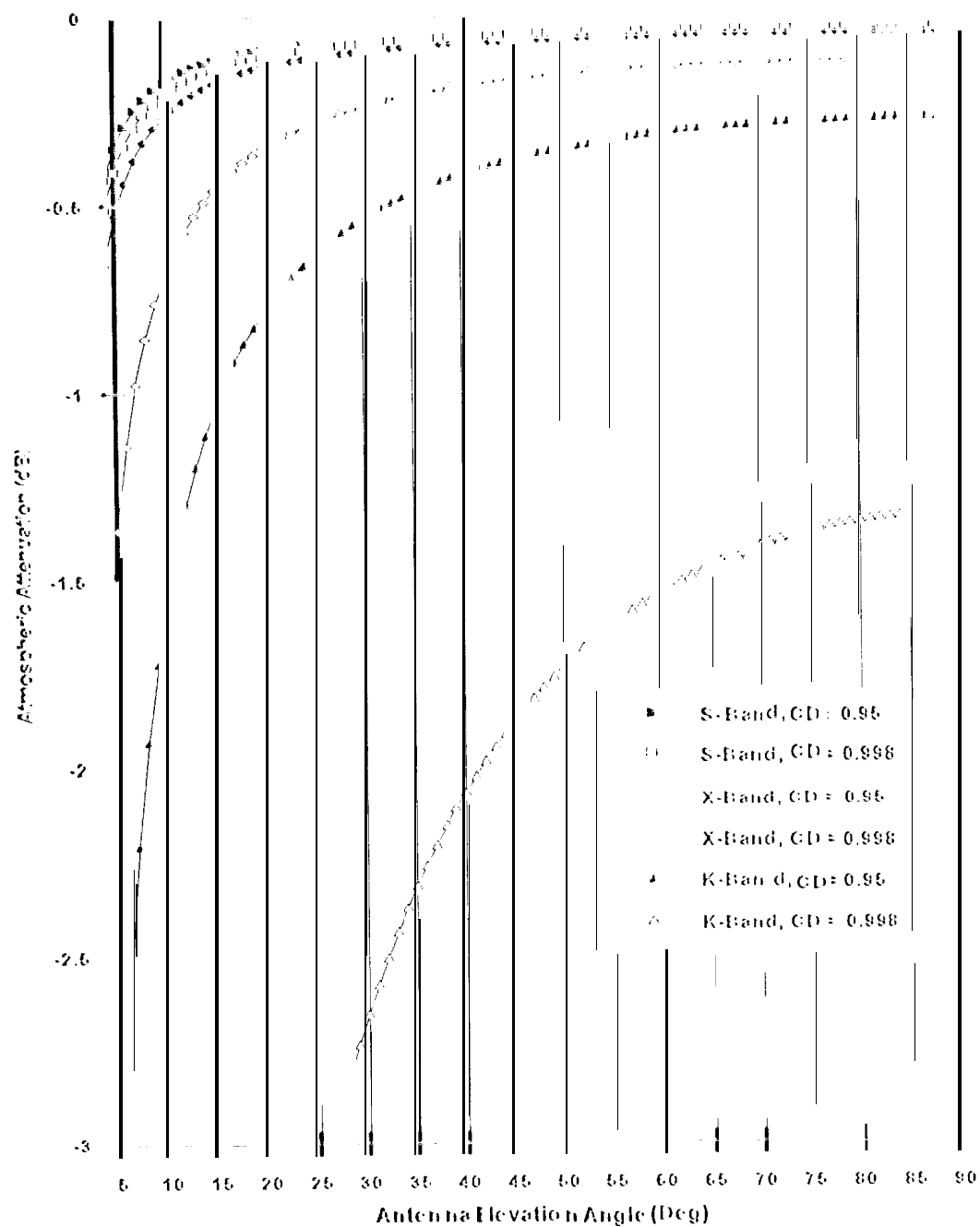


Figure 2. Atmospheric Attenuation as a Function of Antenna Elevation Angle

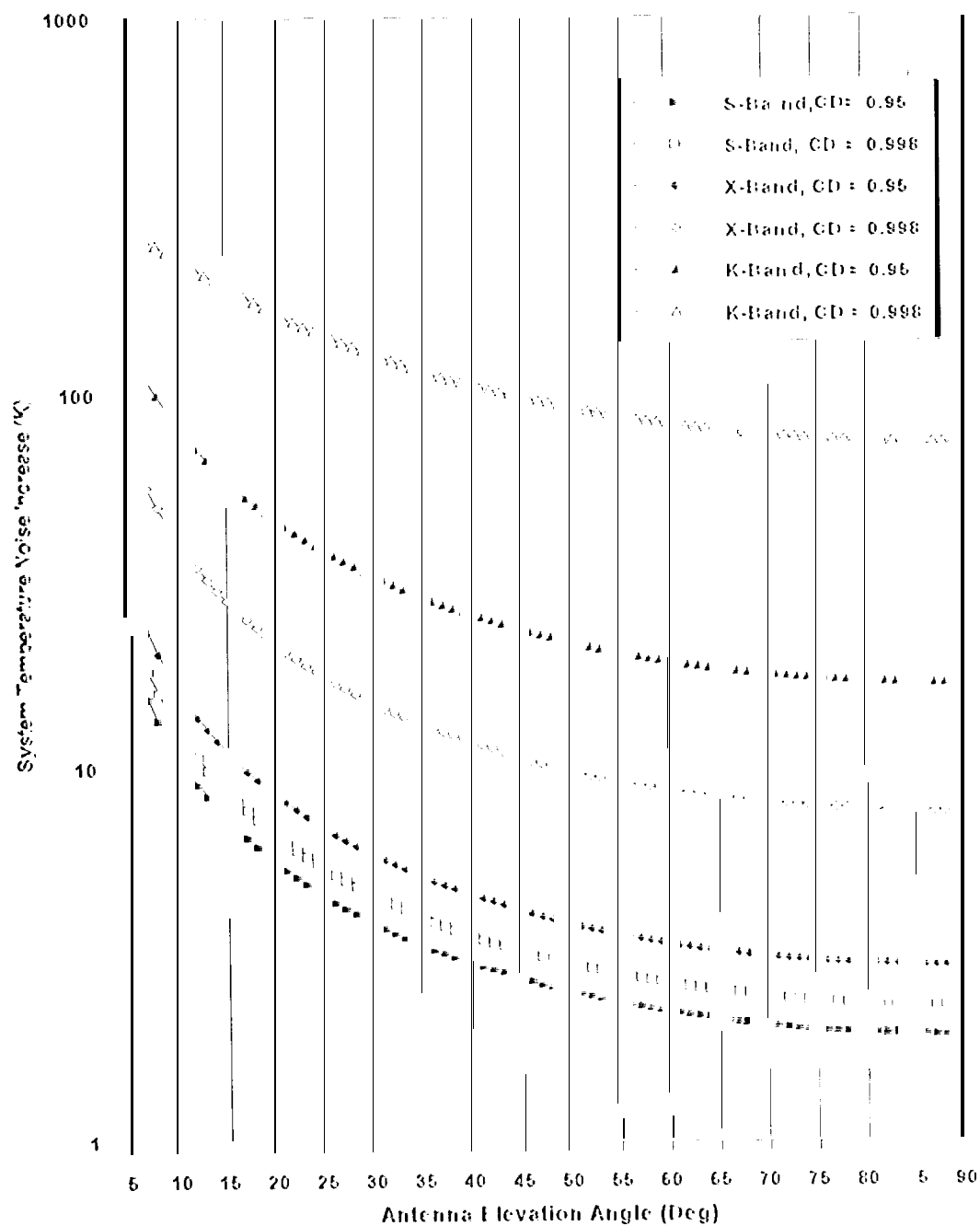


Figure 3. System Noise Temperature Increase as a Function of Antenna Elevation Angle

5.0 Conclusion

The paper presented a method used to calculate the system noise temperature increase and atmospheric attenuation due to weather at the NASA/JPL tracking stations at different frequencies. It is intended that the method described here will help the user generate the loss numbers to be used in the CCSDS design control table..

REFERENCES

1. "Deep space Network / Flight Project Interface Design Handbook, 810-5, Volume 1: Existing DSN Capabilities" Telecommunications Interfaces, atmospherics TCI - 40.